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(71) Applicant: 000006013

Mitsubishi Denki K.K.

2-3 Marunouchi-2-chome, Chiyoda-ku, Tokyo-to, Japan

(72) Inventor: Kentaro YANO

c/o Mitsubishi Denki K.K. Seigyo Seisakujo, 1-2 Wadazakicho-1-chome, Hyogo-ku, Kobe-shi, Japan

(72) Inventor: Yoshihisa MITA

c/o Mitsubishi Denki K.K. Seigyo Seisakujo, 1-2 Wadazakicho-1-chome, Hyogo-ku, Kobe-shi, Japan

(74) Agent: Patent Attorney H. Taro (and two others)

(54) Title of the Invention: Process line tension controlling apparatus

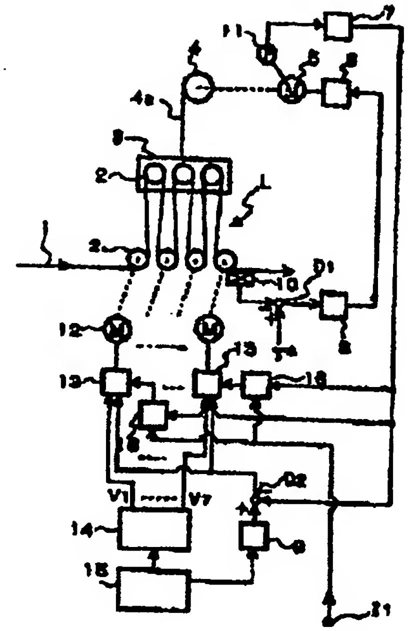
(57) Abstract

Problem:

To provide process line tension controlling apparatus with which fluctuations in the tension of the strip which is being transported in the looper are suppressed and a product which has superior quality can be obtained.

Means of Resolution:

The moment of inertia of the strip 1 which is stored in the looper L is calculated by means of a compensation computer 16 from data such as the width, thickness and density of the strip 1 which is being taken in and the height of the carriage 3 of the looper L, the gain of a speed controller 13 is adjusted by a computing compensator 16 in accordance with the moment of inertia and the response characteristics of the speed controller are set so as to follow up in accordance with the fluctuations of the strip 1 and the tension of the strip 1 is held constant.



L: Looper, 1: Strip, 2: Helper rolls, 3: Carriage, 4: Drum, 4a: Wire, 5: Motor (position controlling means), 6: Speed controlling apparatus (position controlling means) 7: position computer (position controlling means), 8: Compensator (position controlling means), 9: Speed computer (speed controlling means), 10: Tension detectors (tension detecting means), 11: Detector (position controlling means), 12: Motor (speed controlling means), 13: Speed controller (speed controlling means), 14: Speed commander (speed controlling means), 15: Speed setter (speed controlling means), 16: Compensation computers (computing means, compensation means), D_1: Computer (position controlling means), D_2: Computer (speed controlling means)

Scope of the Patent Claim

[Claim 1]

Process line controlling apparatus which is furnished with a looper in which the strip is stored between a plurality of helper rolls, a speed controlling means which controls the rate of rotation of the abovementioned helper rolls and a position controlling means which controls the position of the carriage to which at least some of the abovementioned helper rolls are fitted in which there are established a computing means which computes the moment of inertia of the strip which is being stored in the abovementioned looper and a compensating means which compensates the response characteristics of the aforementioned speed controlling means in accordance with the moment of inertia of the strip computed by said computing means.

[Claim 2]

Process line controlling apparatus which is furnished with a looper in which the strip is stored between a plurality of helper rolls, a speed controlling means which controls the rate of rotation of the abovementioned helper rolls and a position controlling means which controls the position of the carriage to which at least some of the abovementioned helper rolls are fitted in which there are established a computing means which computes the moment of inertia of the strip which is being stored in the abovementioned looper and a compensating means

which compensates the response characteristics of the abovementioned position controlling means in accordance with the moment of inertia of the strip computed by said computing means.

[Claim 3]

Process line controlling apparatus which is furnished with a looper in which the strip is stored between a plurality of helper rolls, speed controlling means which have a control circuit which has two degrees of freedom which control the rates of rotation of the abovementioned individual helper rolls and a position controlling means which controls the position of the carriage to which at least some of the abovementioned helper rolls are fitted in which there are established a computing means which computes the moment of inertia of the strip which is being stored in the abovementioned looper and a compensating means which compensates the response characteristics of the abovementioned position controlling means in accordance with the moment of inertia of the strip computed by said computing means.

[Claim 4]

Process line controlling apparatus which is furnished with a looper in which the strip is stored between a plurality of helper rolls, speed controlling means which control the rates of rotation of the abovementioned helper rolls and a position controlling means which has a circuit which has two degrees of freedom which controls the position of the carriage to which at

least some of the abovementioned helper rolls are fitted in which there is established a compensating means which detects acceleration and deceleration command signals for the abovementioned carriage of the abovementioned position controlling means and with which, during the acceleration and deceleration of the abovementioned carriage in accordance with said acceleration and deceleration command signals, the abovementioned position controlling means controls in such a way that acceleration and deceleration command signals of a theoretical load model control system of the abovementioned control circuit which has two degrees of freedom are supplied to the abovementioned carriage.

[Claim 5]

Process line controlling apparatus which is furnished with a looper in which the strip is stored between a plurality of helper rolls, speed controlling means which control the rates of rotation of the abovementioned helper rolls and a position controlling means which controls the position of the carriage to which at least some of the abovementioned helper rolls are fitted in which there are established tension detecting means which detect the tension of the abovementioned strip which are established at least on the entry side and the exit side of the abovementioned looper, and a compensating means which compensates the speed control values of the abovementioned speed

controlling means on the basis of the tension values of the abovementioned strip detected by said entry side and exit side tension detecting means.

[Claim 6]

Process line controlling apparatus which is furnished with a looper in which the strip is stored between a plurality of helper rolls, speed controlling means which control the rates of rotation of the abovementioned helper rolls and a position controlling means which controls the position of the carriage to which at least some of the abovementioned helper rolls are fitted in which the abovementioned position controlling means is furnished with a wire from which the abovementioned carriage is suspended, a tension detecting means which detects the tension in said wire, a drum on which said wire is wound, a motor which drives said drum, a controlling device which controls said motor and a compensating means which compensates the control value for the abovementioned motor of the abovementioned controlling device on the basis of the tension value detected by the abovementioned tension detecting means.

[Claim 7]

Process line controlling apparatus which is furnished with a looper in which the strip is stored between a plurality of helper rolls, speed controlling means which control the rates of rotation of the abovementioned helper rolls and a position

controlling means which controls the position of the carriage to which at least some of the abovementioned helper rolls are fitted in which the abovementioned speed controlling means are furnished with a roll which is rotated along with the movement of the abovementioned carriage, a detector which detects the extent of the rotation of said roll, a computing means which computes the position of the abovementioned carriage from the detected value of said detector, and a compensating means which compensates the rates of rotation of the abovementioned helper rolls on the basis of the output value of said computing means.

Detailed Description of the Invention

[0001]

Industrial Field of Application

The invention concerns process line tension controlling apparatus which controls the tension of strip steel, for example, where a looper is established in a process line such as a steel production line.

[0002]

Prior Art

In general, if the tension value of a strip of steel, for example, on a process line fluctuates, this has a major effect of the strip thickness precision and uniformity of surface treatment etc. of the product and so the process must be operated continuously while maintaining a constant tension even

when there are various external influences. Consequently, a looper is established and material is stored in the looper so that the operation of the process line need not be stopped even in those cases where interruptions occur in the operation of the process line because of coil insertion or welding for example and tension control apparatus such that the operation can be carried out continuously even if short term interruptions of the operation do arise is widely used.

[0003]

A constructional drawing which shows one embodiment of conventional tension controlling apparatus with which tension control is carried out on a process line where a looper has been established in this way is shown in Figure 8. In this drawing, 1 is the strip of steel, for example, and L is the looper in which the strip 1 is stored. Moreover, 2 are the helper rolls of the looper L and there are four of these on the bottom side and three on the top side, and the strip 1 can be formed into loops and stored between these top and bottom helper rolls 2. Furthermore, the helper rolls 2 are driven in such a way that material transportation is carried smoothly. Moreover, 3 is the carriage of the looper L which controls the loop size of the strip 1, and the top three helper rolls 2 are fitted to this carriage 3.

[0004]

Moreover, 4 is a drum for controlling the height of the carriage 3, 4a is a wire from which the carriage 3 is suspended, 5 is a motor which drives the drum 4, 6 is speed controlling apparatus which controls the speed of the motor 5, 11 is a detector for detecting the position of the carriage 3 in which a pulse oscillator which is fitted to the end of the shaft of the motor 5 is used, and 7 is a position computer which computes the position of the carriage 3 from the output of the detector 11.

[0005]

Moreover, 10 is a tension detector which detects the tension of the strip 1 inside the looper L, D_1 is a computer which computes and puts out the difference between the tension detected by the tension detector 10 and the set tension value T*, 8 is a compensator which carries out a compensation computation for controlling the tension of the strip 1, 12 are motors which drive the helper rolls 2 and seven of these are established independently corresponding to each of the seven helper rolls 2, 13 are speed controllers which control the speeds of the motors 12 and seven of these are established independently corresponding to each of the seven motors 12. Moreover, 15 is a speed setter which sets the target speed of the strip 1, 14 is a speed commander which puts out the drive speed command signals V_1 to V_7 to the seven motors 12 respectively on the basis of the set speed which has been set by

the speed setter 15, 9 is a speed compensator which compensates the rates of rotation of the motors 12 on the basis of the set speed set by the speed setter 15, and D_2 is a computer which computes and puts out the difference between the output signals of the speed compensator 9 and the position computer 7.

[0006]

The operation of this tension controlling apparatus is described below. The strip 1 which is being carried in the looper L is introduced by the helper rolls 2 of the looper 1 and formed into loops between the bottom side helper rolls 2 and the top side helper rolls 2 and stored inside the looper L. The carriage 3 is moved up and down by means of the motor 5 on the wire 4a which is wound on the drum 4 to change the amount of strip 1 inside the looper L.

[0007]

Control of the amount of strip 1 stored inside the looper L is carried out in the following way. First of all, the position of the carriage 3 is determined by the rotation of the motor 5 and so the number of revolutions of the motor 5 is detected by the detector 11 and said number of revolutions is computed by the position computer 7 and put out as a position signal for the carriage 3. The rates of rotation of the motors 12 are controlled by the speed controllers 13 in accordance with the difference between this position signal and the command value of

the speed compensator 9 and by this means the rotation of the helper rolls 2 is controlled and the amount of strip stored is controlled by controlling the amount of strip 1 being sent onward.

[0008]

On the other hand, the tension of the strip 1 is detected by the tension detector 10, the difference between the actual tension value and the set tension value T* is obtained by means of the computer D_1, a compensation signal based on this difference signal is computed by the compensator 8, the motor 5 is controlled by the speed controlling apparatus 6 on the basis of this compensation signal, and the tension of the strip 1 is controlled in such a way as to become normally equal to the set tension value T* by this means.

[0009]

Problems to be Resolved by the Invention

Since the conventional process line tension controlling apparatus is constructed in the way indicated above, each control compensator has a certain specified state set as a prerequisite and so tension changes in the strip which is being transported inside the looper are generated by changes in the size of the strip and changes in the position of the looper and by changes in the response of the speed controllers of the helper rolls when the line is accelerating or decelerating, and

there is a problem in that this has an adverse effect on product quality.

[0010]

The present invention is intended to resolve problems such as that indicated above, and the first aim of the invention is to provide tension controlling apparatus which provides a process line with which, even if there are fluctuations in the moment of inertia of the strip in the looper due to changes in the width, thickness, density and the like of the strip, compensation is carried out in such a way that the speed response of the helper rolls is held constant in accordance with these changes in the moment of inertia, fluctuations in the tension of the strip which is being transported in the looper are suppressed and excellent product performance can be obtained.

[0011]

A second aim of the invention is to provide tension controlling apparatus which provides a process line with which, even if there are fluctuations in the moment of inertia of the strip in the looper due to changes in the width, thickness, density and the like of the strip, compensation is carried out in such a way that the response of the position control of the carriage is held constant in accordance with the changes in the moment of inertia, fluctuations in the tension of the strip

which is being transported inside the looper are suppressed and excellent product quality can be obtained.

[0012]

A third aim of the invention is to provide tension controlling apparatus which provides a process line with which, during acceleration and deceleration of the helper rolls, acceleration and deceleration command signals in accordance with the theoretical load model are supplied to the motors which drive each of the helper rolls, the compensated speeds of the helper rolls are improved, fluctuations in the tension of the strip which is being transported in the looper are suppressed and excellent product quality performance can be obtained.

[0013]

A fourth aim of the invention is to provide tension controlling apparatus which provides a process line with which, during acceleration and deceleration of the carriage, acceleration and deceleration command signals in accordance with the theoretical load model are supplied to the motor which drives the carriage, fluctuations in the tension of the strip which is being transported in the looper are suppressed and excellent product quality performance can be obtained.

[0014]

A fifth aim of the invention is to provide tension controlling apparatus which provides a process line with which

the speed control values of the speed controlling means are compensated on the basis of the tension values on the entry side and exit side of the looper, fluctuations in the tension of the strip which is being transported in the looper are suppressed and excellent product quality performance can be obtained.

[0015]

A sixth aim of the invention is to provide tension controlling apparatus which provides a process line with which the control value of the motor which drives the carriage is compensated on the basis of the tension value of the wire from which said carriage is suspended, fluctuations in the tension of the strip which is being transported in the looper are suppressed and excellent product quality performance can be obtained.

[0016]

A seventh aim of the invention is to provide tension controlling apparatus which provides a process line with which the extent of rotation of a roll which is rotating and moving on the carriage is detected and the position of the carriage is computed, fluctuations in the tension of the strip which is being transported in the looper are suppressed by compensating the drive speed of the helper rolls on the basis of the computed value and excellent product quality performance can be obtained.

[0017]

Means of Resolving These Problems

The process line tension controlling apparatus of the invention of claim 1 has established therein a computing means which computes the moment of inertia of the strip which is being stored in the looper and a compensating means which compensates

the response characteristics of the speed controlling means which control the rates of rotation of the helper rolls in accordance with the moment of inertia of the strip computed by said computing means.

[0018]

The process line controlling apparatus of the invention of claim 2 has established therein a computing means which computes the moment of inertia of the strip which is being stored on the abovementioned looper and a compensating means which compensates the response characteristics of the position controlling means which controls the position of the carriage in accordance with the moment of inertia of the strip computed by said computing means.

[0019]

The process line controlling apparatus of the invention of claim 3 has established therein a compensating means which detects the acceleration and deceleration command signals for the abovementioned helper rolls of the speed controlling means which control the rate of rotation of the helper rolls and with which, during the acceleration and deceleration of the abovementioned helper rolls in accordance with said acceleration and deceleration command signals, the abovementioned speed controlling means is controlled in such a way that the acceleration and deceleration command signals of the theoretical

load model control system of this control circuit which has two degrees of freedom are supplied to the abovementioned helper rolls.

[0020]

The process line controlling apparatus of the invention of claim 4 has established therein a compensating means which detects the acceleration and deceleration command signals for the abovementioned carriage of the position controlling means which controls the position of the carriage and with which, during the acceleration and deceleration of the abovementioned carriage in accordance with said acceleration and deceleration command signals, the abovementioned position controlling means is controlled in such a way that the acceleration and deceleration command signals of the theoretical load model control system of this control circuit which has two degrees of freedom are supplied to the abovementioned carriage.

[0021]

The process line controlling apparatus of the invention of claim 5 has established therein tension detecting means which detect the tension of the abovementioned strip, which are established at least on the entry side and exit side of the abovementioned looper, and a compensating means which compensates the speed control value of the abovementioned speed controlling means which control the rates of rotation of the

helper rolls on the basis of the tension values of the abovementioned strip detected by said entry side and exit side tension detecting means.

[0022]

The process line controlling apparatus of the invention of claim 6 is such that the position controlling means which detects the position of the carriage is furnished with a wire from which the abovementioned carriage is suspended, a tension detecting means which detects the tension in said wire, a drum on which said wire is wound, a motor which drives said drum, controlling apparatus which controls said motor and a compensating means which compensates the control value for the abovementioned motor of the abovementioned controlling apparatus on the basis of the tension value detected by the abovementioned tension detecting means.

[0023]

The process line controlling apparatus of the invention of claim 7 is such that the speed controlling means which controls the rates of rotation of the helper rolls is furnished with a roll which is rotated along with the movement of the abovementioned carriage, a detector which detects the extent of the rotation of said roll, a computing means which computes the position of the abovementioned carriage from the output value of said detector and a compensating means which compensates the

rates of rotation of the abovementioned helper rolls on the basis of the output value of said computing means.

[0024]

Action

The process line tension controlling apparatus of the invention of claim 1 compensates the response characteristics of the speed controlling means in accordance with the moment of inertia of the strip and, by this means, the speed responsiveness of the helper rolls is changed and matched with the change in speed of the strip and, by this means, the tension of the strip can be held constant.

[0025]

The process line tension controlling apparatus of the invention of claim 2 is able to hold the control response of the looper constant irrespective of the position carriage by compensating the response characteristics of the position controlling means in accordance with the moment of inertia of the strip and, by this means, the speed fluctuations of the strip are matched, the carriage is moved and the tension of the strip can be held constant.

[0026]

The process line tension controlling apparatus of the invention of claim 3 is such that the helper rolls are controlled by acceleration and deceleration commands of the

theoretical load model system of the control circuit which has two degrees of freedom of the speed controlling means during acceleration and deceleration of the helper rolls and so the speed control responsiveness of the helper rolls can be heightened without being affected by noise, the ability of each helper roll to follow the command signals is raised, the matching of the speeds of the helper rolls can be improved and, by this means, the tension of the strip can be held constant.

[0027]

The process line tension controlling apparatus of the invention of claim 4 is such that, during the acceleration and deceleration of the carriage, the carriage is controlled by acceleration and deceleration commands of the theoretical load model control system of the control circuit which has two degrees of freedom of the position controlling means and so the position control response characteristics of the carriage can be heightened without being affected by noise, the ability of the carriage to follow the command signals is heightened and, by this means, the tension of the strip can be held constant.

[0028]

With the process line tension controlling apparatus of the invention of claim 5, the tensions of the strip on the entry side and the exit side of the looper can be kept equal by compensating the speed control values of the helper rolls on the

basis of the tension values of the strip detected by the tension detecting means on the entry side and the exit side of the looper.

[0029]

With the process line tension controlling apparatus of the invention of claim 6, the position control of the carriage is compensated on the basis of the tension of the wire from which the carriage is suspended and so follow-up of the carriage is improved and the tension of the strip can be held constant.

[0030]

With the process line tension controlling apparatus of the invention of claim 7, the position of the carriage can be known precisely since the position of the carriage is computed on the basis of the extent of rotation of a roll which rotates together with the movement of the carriage and, in its turn, the tension of the strip can be held constant precisely.

[0031]

Illustrative Examples

Illustrative Example 1

Illustrative example 1 of the invention is described below with reference to the drawings. Moreover, in the drawings of all of the illustrative examples described below, structural elements which are the same as the structural elements of the example described before said illustrative examples as the

conventional example shown in Figure 8 are marked with the same key numbers etc. as in Figure 8 in the illustrative examples and further description is omitted.

[0032]

Figure 1 is a constructional drawing which shows the structure of Illustrative Example 1 of this invention. In this drawing, I_1 is an input terminal through which data such as the width W, the thickness T and the density σ etc. of the strip 1 are input, and 16 are compensation computers (computing means, compensating means) which carry out gain compensation of the speed controllers 13 of the helper rolls 2 on the basis of the width W, the thickness T and the density σ etc. of the strip 1 which has been input from the input terminal I_1 and the position of the carriage 3 which has been detected by the detector 11, and seven of these are established corresponding individually with the seven speed controllers 13. Moreover, the drum 4, the wire 4a, the motor 5, the speed controlling apparatus 6, the position computer 7, the compensator 8, the detector 11 and the computer D_1 constitute the position controlling means and the motors 12, the speed controllers 13, the speed commander 14, the speed setter 15, the speed computer 9 and the computer D_2 constitute the speed controlling means.

[0033]

The operation of this illustrative example is described

below. The looper L is generally controlled in such a way that the strip 1 is taken up for storage (or fed out) as the carriage 3 is being raised (or being lowered) when the coil is being changed, for example, while carrying out position control of the carriage 3 and tension control of the strip 1, but at this time the control must be such that the helper rolls 2 are accelerated (or decelerated) and fluctuations in the tension do not arise. However, with the conventional tension controlling apparatus, the speed control gain of each speed controller 13 is set to a certain fixed value and so the responsiveness of the looper L changes in response to changes in the structural constants such as the material size of the strip 1 and, as a result of this, there are inevitably cases where tension fluctuations occur as there is no matching of the changes in speed of the strip 1 before and after the looper L and the changes in responsiveness.

[0034]

In order to prevent this from occurring, in this illustrative example, the position of the carriage 3 is detected with the detector 11 and the position computer 7 and the width W, thickness T and density σ of the strip 1 are input to the compensation computers 16 and gain compensation of the speed controllers 13 is carried out by the compensation computers 16 and control is such that the helper rolls 2 generally have a fixed responsiveness.

[0035]

If, in the case where one helper roll 2 is being driven for one strand of the strip 1, the height with respect to the helper rolls 2 on the bottom side of the carriage 3 is L and the roll diameter of the helper roll 2 is D_2, the moment of inertia GD_1^2 of the machine side on which the helper roll 2 is supported is given by the following equation:

$$GD_1^2 = (W*T*L)*\sigma*(D_2)^2$$

In this illustrative example, the abovementioned calculation is carried out in the compensation computers 16 and the computed values are used as a gain compensation of each helper roll 2 speed controller 13.

[0036]

Hence, in a case where one helper roll 2 is driven for N stands, the gain compensation is given by the following equation:

$$GD_1^2 = N*(W*T*L)*\sigma*(D_2)^2$$

[0037]

By correcting the total moment of inertia GD^2 in the way indicated above, it is possible to carry out the torque

calculation at the time of acceleration or deceleration of the production line of the strip 1 precisely. Hence, whatever the position of the carriage 3, the speed control response of each helper roll 2 can be held constant. As a result of this, the acceleration and deceleration of the helper rolls 2 can be realized in a state where the changes in speed of the strip 1 before and after the looper L are matched and no tension fluctuations are produced in the strip 1.

[0038]

Illustrative Example 2

Figure 2 is a constructional drawing which shows the construction of Illustrative Example 2 of this invention. In this drawing, I_2 is an input terminal to which the number of strands supported on the looper L is input and 16_A is a compensation computer (computing means, compensating means) which calculates the gain compensation value for the speed controlling apparatus 6 on the basis of the position of the carriage 3 which has been detected by the detector 11, the width W, thickness T and density σ of the strip 1 which have been input from the input terminal I_1 and the number of stands supported on the looper L.

[0039]

The operation of this illustrative example is described below. First of all, the position of the carriage 3 is detected

by the detector 11 and the position computer 7 and at the same time the width W, thickness T and density σ of the strip 1 from the input terminal I_1 and the number of strands from the input terminal I_2 are input to the compensation computer 16_A.

[0040]

If the height of the carriage is L and the number of strands supported on the carriage 3 is n, then the mass M of the strands $M = (W*T*L)*\sigma*n$. If the diameter of the drum 4 is D_1, then the moment of inertia GD_2^2 of the strip imposed on the motor 5 is $GD_2^2 = M*(D_1)^2$.

[0041]

In this illustrative example, the abovementioned calculation is carried out in the compensation computer 16_A and, by carrying out gain compensation of the speed controlling apparatus 6 on the basis of the calculated value, the torque calculation when the production line is accelerating and decelerating of the strip 1 can be carried out precisely. Hence, whatever the position of the carriage 3, the control response of the looper L can be held constant. As a result of this, acceleration and deceleration of the helper rolls can be carried out while matching the speed changes of the strip 1 before and after the looper L and fluctuations of the tension in the strip 1 do not arise.

[0042]

Illustrative Example 3

A constructional drawing which shows the structure of Illustrative Example 3 of this invention is shown in Figure 3. In this drawing, 17 are compensators (compensating means) which control the outputs of the speed controllers 13 and they are established for each of the speed controllers 13. Furthermore, control circuits which have two degrees of freedom are used in the speed controllers 13 of this illustrative example.

[0043]

The actual construction of a speed controller 13 in which a control circuit which has two degrees of freedom is used is shown by the block diagram in Figure 4. In this drawing, I_3 is an input terminal to which the outputs of the speed commander 14 and the computer D_2 are input, D_3 and D_5 are computers which compute and put out the difference between the two inputs which are being input respectively, 17a is a first speed controller which computes the speed control signal for the motor 12 on the basis of the difference signal put out from the computer D_3, 17b is a compensator which switches between the output signal of the first speed controller 17a and a prescribed output signal and makes an output on the basis of the compensation signal put out from the compensator 17, D_4 is a computer which adds together the output of the compensator 17b and the output of the second speed controller 18 described hereinafter and puts out the result, 19

is a first electrical current controller which computes the electrical current value in accordance with said output signal on the basis of the output signal computer D_4, 21 is a thyristor device which controls the electrical current which is flowing in the coil of the motor 12 on the basis of the output signal of the first current controller 19, 23 is a speed detector which detects the rate of rotation of the motor 12, and the first speed controller 17a, the compensator 17b, the first electrical current controller 19, the thyristor device 21 and the speed detector 23 form a first control system which detects the actual rate of rotation of the motor and executes control in such a way that this conforms with a standard value (the speed command signal which is put out from the speed commander 14). Moreover, 17b has a function such as that shown in Figure 4(2). That is to say, switching between and output from the first speed controller 17a which is being input at the terminal I_5 and the signal which is being input at the input terminal I_6 is carried out on the basis of the compensation signal put out from the compensator 17 which is input at the terminal I_4.

[0044]

Moreover, 18 is a second speed controller which computes an ideal speed control signal with no noise for the motor 12 based on the difference signal which is put out from the computer D_6, 20 is a second electrical current controller which computes the

ideal electrical current control value on the basis of the output signal of the second speed controller 18, and 22 is a theoretical load model which includes the motor 12 and other loads such as the helper rolls 2 and gears etc., and the computer D_6, the speed controller 18, the electrical current controller 20 and the theoretical load model 22 form a second control system.

[0045]

The distinguishing feature of this control system which has two degrees of freedom is that it has a first control system which is generally used as speed controlling apparatus for the motor and a second control system which computes the speed control value separately on the basis of the same speed command signal. The detection signal of the speed detector 23 which detects the rate of rotation of the motor 12 which has a load such as the various gears and the helper roll 2 includes the torsional oscillation of the helper roll 2 and the like as a ripple and so hunting is inevitable if the gain of the first speed controller 17a rises. Here, a theoretical load model 22 is held in the second control system in the control system which has two degrees of freedom and the ideal speed control signal with no noise is computed by the second speed controller 18. The ideal speed control signal is input to the first electrical current controller 19 and the speed control characteristics are

improved.

[0046]

The operation of this system is described below. First of all, the second speed controller 18 of the second system incorporates the actual load of the motor 12 including the gears and the helper rolls 2 and the thyristor device 1 for the theoretical load model 22 and generates an ideal speed command signal in such a way that an ideal speed control response is obtained. Then, the compensator 17 detects the timing at which the speed command signal put out from the speed commander 14 is acceleration or deceleration and said compensator 17b is controlled in such a way that, during this time, the output of the compensator 17b is switched to the signal from the input terminal I_6. By this means, when said speed command signal is acceleration or deceleration, the output of the first speed controller 17a of the first control system is blocked and the acceleration or deceleration torque command signal at the output from the speed controller 18 of the second control system is applied to the electrical current controller 19.

[0047]

As a result, hunting does not arise in this illustrative example and the gain of both the first speed controller 17a of the first control system and the second speed controller 18 of the second control system can be raised and the speed control

response can be heightened. That is to say, the follow-up of the speed command signal for each helper roll 2 can be improved, the uniformity of speed of each helper roll 2 is improved and fluctuations in tension can be reduced.

[0048]

Illustrative Example 4

A case where the helper rolls 2 where controlled with two degrees of freedom was described in Illustrative Example 3 but of course the same effect is obtained by subjecting other motors, such as the motor 5 for example, to control with two degrees of freedom.

[0049]

Illustrative Example 5

A constructional drawing which shows the structure of Illustrative Example 5 of this invention is shown in Figure 5. In this drawing, D_6 is a computer which computes and puts out the difference between the output signals of the tension detectors (tension detecting means) 10 which are established on the entry side and the exit side of the looper L and 26 is a compensator which compensates the speed of each helper roll 2 on the basis of the difference signal which is put out from the computer D_6.

[0050]

The operation of this illustrative example is described below. The detected value T_1 of one tension detector 10 which is

established on the entry side of the looper L and the detected value T_2 of the other tension detector 10 which is established on the exit side of the looper L are obtained, the difference between the two is calculated by the computer D_6 and the output indicated below is input to the compensator 26.

$$\Delta T = T_1 - T_2$$

The compensator 26 computes and puts out a compensating amount for each helper roll on the basis of this difference signal in the following way. Thus, if it is assumed that the total number of helper rolls 2 is N, the compensating amount Q_i for each single helper roll 2 is given by the following equation:

$$Q_i = (i/N)*\Delta T*G$$

Here, G is the gain. This value is added to the control amount of each speed controller 13 and the tensions of the strip 1 on the entry side and exit side of the looper L are equalized and made stable.

[0051]

Illustrative Example 6

A constructional drawing which shows the structure of Illustrative Example 6 of this invention is shown in Figure 6.

In this drawing, 27 is a tension detector which detects the tension of the wire 4a between the drum 4 and the carriage 3, D_7 is a computer which computes and puts out the difference between the actual tension value of the wire 4a detected by the tension detector 27 and the ideal tension T_C* and 28 is a compensator which puts out to the speed controlling apparatus 6 a torque component compensation signal which compensates the speed of the looper L on the basis of the output value of the computer D_7. This illustrative example improves the responsiveness of the tension control by establishing a detecting means for the tension on the generating side.

[0052]

The operation of this illustrative example is described below. The wire used for the wire 4a which drives the carriage 3 is generally a wire which is not subject to stretching and contraction but even so stretching and contraction occur when the carriage 3 is being driven and the tension in the wire 4a changes. These changes in the tension disturb the position control of the carriage 3 and torque control and inevitably make tension control of the strip 1 difficult. In this illustrative example, the ideal tension value T_C* of the wire 4a and the detected value of the tension detector 27 are compared and the torque compensating amount computed by the compensator 28 is added to the control signal of the speed controlling apparatus

6. That is to say, tension control of the wire 4a is carried out as a minor loop of the tension control of the strip 1 and the tension control response of the strip 1 is improved.

[0053]

Illustrative Example 7

A constructional drawing which shows the structure of Illustrative Example 7 of this invention is shown in Figure 7. In this drawing, 30 is a roll for detecting the position of the carriage 3 of the looper, 29 is a wire which links the roll 30 and the carriage 3, 31 is a rotation detector which is fitted to the shaft of the roll 30 and 32 is a computer (computing means) which calculates the position of the carriage 3 on the basis of the value for the number of rotations put out from the rotation detector 31.

[0054]

The operation of this illustrative example is described below. In conventional tension controlling apparatus, as shown in Figure 8, the position of the carriage 3 is detected from the number of revolutions of the motor 5 with the position detector 11 which is fitted to the end of the shaft of the motor 5. However, with the conventional system, the end of the shaft of the motor 5 and the carriage 3 are physically separated and adequate position detection precision for carriage 3 is not obtained. In this illustrative example, the amount of movement

of the carriage 3 is converted into an amount of rotation by the roll 30 which is fitted for the exclusive use of the carriage position detector and the wire 29 which is fitted to the carriage 3 and the precise position of the carriage 3 can be detected by means of the rotation detector 31 and the computer 32. Hence, the actual position of the carriage 3 can be detected directly without involving the motor 5.

[0055]

Moreover, in Illustrative Examples 1 to 7 described above, cases where there are one carriage 3 and seven helper rolls 2 have been described, but of course the numbers of carriages and helper rolls are not limited to these numbers and the same results as those described above can be obtained by applying the technical concepts of this invention.

[0056]

Effect of the Invention

As described above, by means of the invention of claim 1, it is possible to hold the speed control response of the helper rolls constant because it is constructed in such a way that the response characteristics of the speed controlling means are compensated in accordance with the moment of inertia of the strip and, by this means, the fluctuation in the tension of the strip which is being transported in the looper is suppressed and it is possible to realize a process line with which superior

product performance can be obtained.

[0057]

By means of the invention of claim 2, it is possible to hold the position control response of the carriage constant because it is constructed in such a way that the response characteristics of the position controlling means are compensated in accordance with the moment of inertia of the strip and, by this means, the fluctuation in the tension in the strip which is being transported in the looper is suppressed and it is possible to realize a process line with which superior product performance can be obtained.

[0058]

By means of the invention of claim 3, the follow-up of the command signal for each helper roll is heightened and the matching of the helper rolls can be improved because it is constructed in such a way that the helper rolls are controlled by means of acceleration and deceleration commands of the theoretical load model control system which has a control circuit which has two degrees of freedom of the speed controlling means and, by this means, the fluctuation in the tension in the strip which is being transported in the looper is suppressed and it is possible to realize a process line with which superior product performance can be obtained.

[0059]

By means of the invention of claim 4, the follow-up of the carriage command signals is heightened since it is constructed in such a way that the carriage is controlled by means of acceleration and deceleration commands of the theoretical load model control system which has a control circuit which has two degrees of freedom of the position controlling means and, by this means, the fluctuation in the tension in the strip which is being transported in the looper is suppressed and it is possible to realize a process line with which superior product performance can be obtained.

[0060]

By means of the invention of claim 5, the tension of the strip can be kept equal on the entry side and exit side of the looper because it is constructed in such a way that the helper roll speed control values are compensated on the basis of the strip tension values detected by tension detecting means on the entry side and exit side of the looper, the fluctuation in the tension of the strip which is being transported in the looper is suppressed and it is possible to realize a process line with which superior product performance can be obtained.

[0061]

By means of the invention of claim 6, the follow-up of the carriage is improved because it is constructed in such a way that the carriage position control is compensated on the basis

of the tension in the wire from which the carriage is suspended, the fluctuation in the tension of the strip which is being transported in the looper is suppressed and it is possible to realize a process line with which superior product performance can be obtained.

[0062]

By means of the invention of claim 7, the position of the carriage is known precisely because it is constructed in such a way that the position of the carriage is computed on the basis of the amount of rotation of a roll which is rotated together with the movement of the carriage, and the fluctuation in the tension of the strip which is being transported in the looper is suppressed and it is possible to realize a process line with which superior product performance can be obtained.

Brief Explanation of the Drawings

Figure 1 is a constructional drawing which shows the structure of Illustrative Example 1 of the invention.

Figure 2 is a constructional drawing which shows the structure of Illustrative Example 2 of the invention.

Figure 3 is a constructional drawing which shows the structure of Illustrative Example 3 of the invention.

Figure 4 is a block diagram which shows the actual construction of the speed controllers 13 of Illustrative Example 3.

Figure 5 is a constructional drawing which shows the structure of Illustrative Example 5 of the invention.

Figure 6 is a constructional drawing which shows the structure of Illustrative Example 6 of the invention.

Figure 7 is a constructional drawing which shows the structure of Illustrative Example 7 of the invention.

Figure 8 is a constructional drawing which shows an example of conventional tension controlling apparatus.

Key to the Drawings

1: Strip, 2: Helper rolls, 3: Carriage, 4: Drum, 4a: Wire, 5: Motor (position controlling means), 6: Speed controlling apparatus (position controlling means) 7: position computer (position controlling means), 8: Compensator (position controlling means), 9: Speed computer (speed controlling means), 10, 27: Tension detectors (tension detecting means), 11: Detector (position controlling means), 12: Motor (speed controlling means), 13: Speed controller (speed controlling means), 14: Speed commander (speed controlling means), 15: Speed setter (speed controlling means), 16, 16_A: Compensation computers (computing means, compensation means), 17, 26, 28: Compensators (compensating means), 30: Roll, 32: Computer (computing means), L: Looper, D_1: Computer (position controlling means), D_2: Computer (speed controlling means).

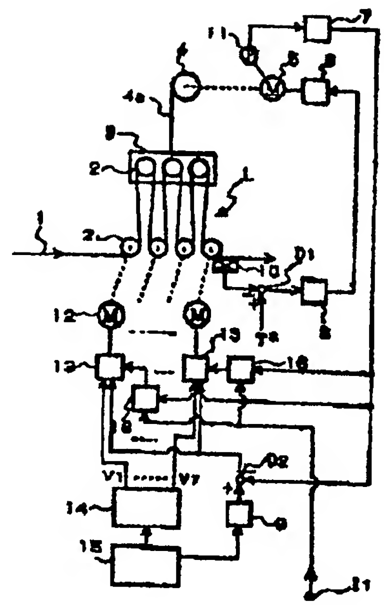
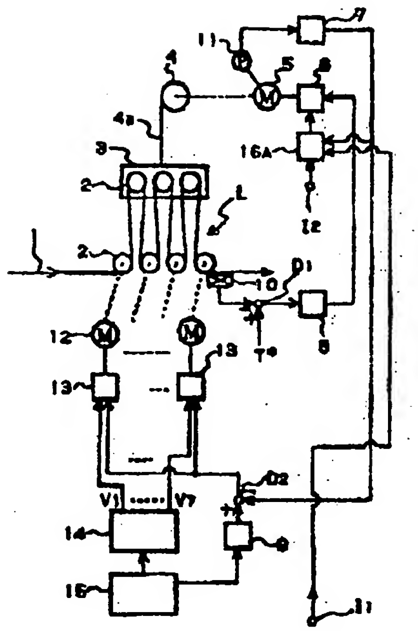


Figure 1

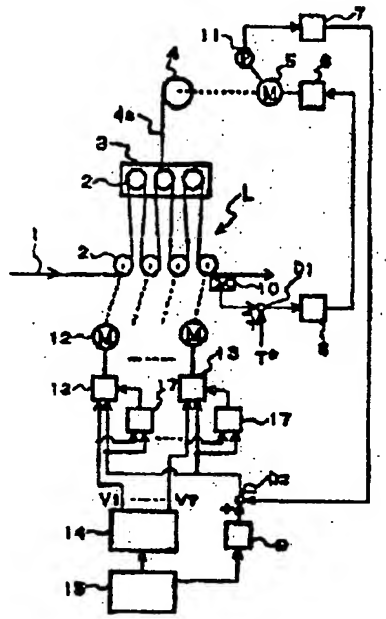
L: Looper, 1: Strip, 2: Helper rolls, 3: Carriage, 4: Drum, 4a: Wire, 5: Motor (position controlling means), 6: Speed controlling apparatus (position controlling means) 7: position computer (position controlling means), 8: Compensator (position controlling means), 9: Speed computer (speed controlling means), 10: Tension detectors (tension detecting means), 11: Detector (position controlling means), 12: Motor (speed controlling means), 13: Speed controller (speed controlling means), 14: Speed commander (speed controlling means), 15: Speed setter (speed controlling means), 16: Compensation computers (computing means, compensation means), D_1: Computer (position controlling means), D_2: Computer (speed controlling means)

Figure 2



16_A: Compensation computers (computing means, compensation means)

Figure 3



17: Compensator (compensating means)

Figure 4

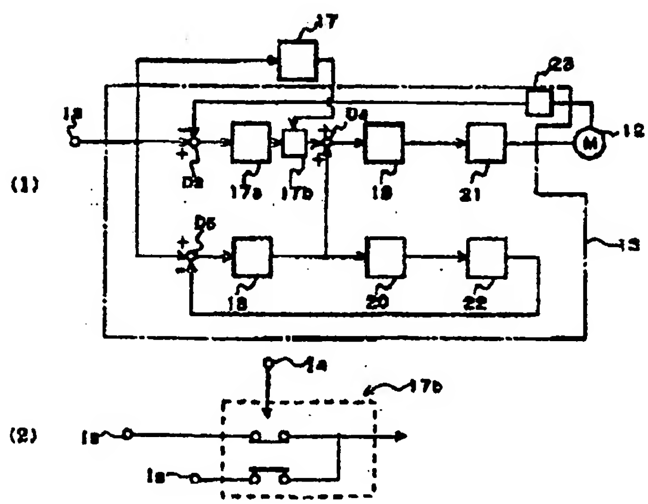
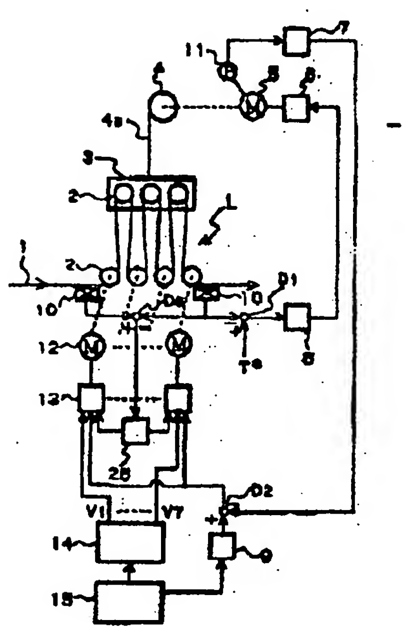
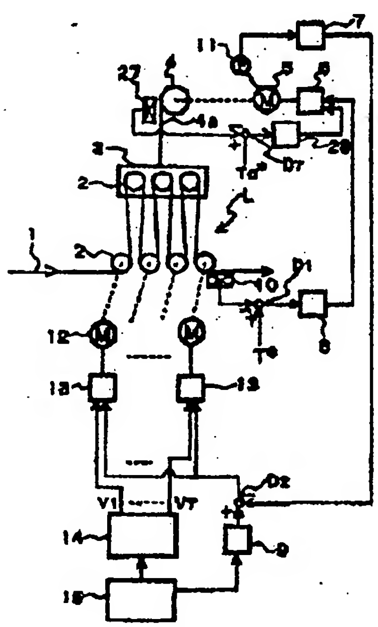


Figure 5



26: Compensator (Compensating means)

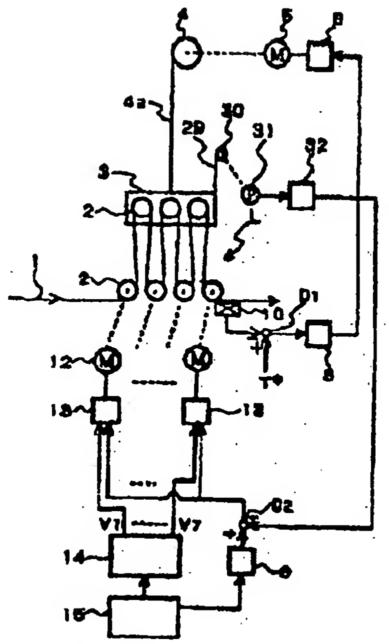
Figure 6



27: Tension detector (tension detecting means)

28: Compensator (compensating means)

Figure 7



30: Roll, 32: Computer (Computing means)

Figure 8